REMARKS/ARGUMENTS

Claim Status

Claims 1-17 are pending. Claim 1 has been amended to include the subject matter of original claims 2-8. Claims 14-17 are added. New claims 14-17 find support in Figures 1-4 respectively. No new matter has been entered.

Claim Objections

Claim 1 is objected to for lack of consistent naming of the source electrode and drain electrode. Per the Examiner's suggestion, line 5 of claim 1 has been amended from "the source and the drain" to "the source electrode and the drain electrode". Accordingly, Applicants request the withdrawal of this objection.

§102(b) and §102(e) Rejections

Claims 1, 5 and 9-13 are rejected under 35 U.S.C. §102(b) as anticipated by *Bao* (US 6,429,040) and under 35 U.S.C. §102(e) as anticipated by *Ong* (US 6,861,664). Applicants respectfully traverse these rejections.

As noted above, claim 1 now includes the subject matter of original claims 2-8. Of this subject matter (i.e., claims 2-8), only that of claim 5 is included in the anticipation rejections. More specifically, the Office asserts that both *Bao* and *Ong* "teaches that the heterocyclic compound containing a nitrogen atom is a compound of the general formula (IV) of claim 5 wherein Z_4 is a six-membered ring and R_{41} and R_{42} are a substituent of a cyclic ring" (page 4, paragraph b; page 7, paragraph f) (emphasis added).

In contrast to the Office's assertion of anticipation, Applicants' claim 5 discloses a compound of formula (IV) wherein "R_{41} and R_{42} each independently represents a hydrogen atom or a substitutent" (emphasis added). Thus, R_{41} and R_{42} being a substituent of a cyclic

ring cannot anticipate R_{41} and R_{42} each independently representing a hydrogen atom or a substituent.

Accordingly, as claim 1 now includes the non-anticipated subject matter of original claims 2-4 and 6-8, as well as the non-anticipated subject matter of claim 5 as explained above, Applicants request withdrawal of the anticipation rejections in view of both *Bao* and *Ong*.

§103(a) Rejections

Claims 1 and 3-12 are rejected under 35 U.S.C. §103(a) as obvious in view of *Jackson* (US 6,720,572), *Klauk* (Solid-State Electronics, Vol. 47, pgs. 297-301) and *Ueda* (US 6,420,057). Additionally, claims 1, 2 and 9-12 are rejected under 35 U.S.C. §103(a) as obvious in view of *Jackson*, *Klauk* and *Taguchi* (JP 2001-357977). Applicants respectfully traverse these rejections.

In summary fashion, the Office has taken the position that it would have been obvious to one skilled in the art to take the organic thin film transistor of *Jackson* and set the channel length (i.e., "distance between the source electrode and the drain electrode") to 5-100 micrometers as disclosed by *Klauk* and to then incorporate the heterocyclic compounds as disclosed by *Ueda* (formulas II-VII) and *Taguchi* (formula I) as the light emitting material of the organic semiconductor layer.

In rebuttal to the Office's position, Applicants offer the following comments with respect to non-obviousness in view of *Jackson*, *Klauk*, *Ueda* and *Taguchi*.

Klauk demonstrates that carrier field-effect mobility elevates and threshold voltage lowers as the channel length is set longer. However, a person skilled in the art would not be motivated to lengthen the channel length of the organic light emitter of *Jackson* according to

the disclosure of *Klauk* because (i) *Klauk* does not teach to lengthen the channel length and (ii) the device structure of *Jackson* is significantly different from the structure of *Klauk*.

(i) *Klauk* mentions that various problems are involved with organic TETs unlike those based on single-crystalline silicon, and further states "organic TFT performance typically suffers from large contact resistance, perhaps to the point where the speed of organic integrated circuits may not be limited by the intrinsic carrier mobility of the organic semiconductor, but by the contact resistance of the TFrs" (see right column, lines 13.18 on page 297). In other words, the purpose of the *Klauk's* study is to evaluate contact resistance by eliminating the influence of the intrinsic carrier mobility from the total carrier field-effect mobility. In order to estimate the contact resistance, *Klauk* prepared a series of pentacene TFrs with channel length ranging from 5 to 100pm, plotted the inverse of drain current versus channel length, extrapolating to a channel length of zero (where the channel resistance disappears), and multiplying by the drain-source voltage (see right column, page 299 to left column, page 800). In conclusion, *Klauk* states "The results show that for pentacene TFTs with typical dimensions, the contact resistance can be many times greater than the channel resistance. Therefore, any design or process improvements specifically directed at a reduction of the contact resistance in organic TFTs should be regarded as equally important to improving the performance of organic electronic devices as improvements directed at increasing the intrinsic carrier mobility of the organic semiconductor material." (left column, lines 8-17 on page 301) Accordingly, a person skilled in the art may be directed to improve the contact resistance in TFTs, but not to lengthen the channel length.

In addition, although Fig.3 shows that carrier field-effect mobility elevates as channel length is set longer, this does not simply mean that device performance is also improved. Field-effect mobility is proportional to the inverse of resistivity (ρ)*, and both channel resistance and contact resistance influence field-effect mobility. When channel length is set

longer, channel resistance increases proportionally, whereas contact resistance stays constant. As a result, the relative influence of contact resistance is reduced, and field-effect mobility increases (see p299 left column, lines 4-6 of *Klauk's* reference). However, when channel length is set extremely long, the relative influence of contact resistance becomes negligibly small, but channel resistance stays proportional to the channel length. Therefore, setting channel length longer does not unlimitedly improve field-effect mobility. In other words, by showing Fig.3, *Klauk* does not indicate to set channel length longer, but does illustrate that field-effect mobility is largely deteriorated by contact resistance, and improving contact resistance would also result in improving the device characteristics. Therefore, a person skilled in the art would not have been motivated to set channel length longer.

Field-effect mobility is defined by the equation $v = \mu E$ where E is electric field and v is carrier velocity. On the other hand, the equation $j = E/\rho$ is known as Ohm's law where j is current density and ρ is resistivity. Further considering the equation $j = env$ where e is charge of carrier and n is carrier density, the equation $p = 1/(e\mu n)$ is derived. (see the attached S. M. Sze "Physics of Semiconductor Devices" p.31 2nd edition). Therefore, when the carriers are either electrons or holes, the mobility within a substance is inversely proportional to the resistivity, and when contact resistance exists, ρ becomes larger, resulting in smaller μ.

Rather, it would have been obvious that longer channel length would result in deteriorating the performance of organic thin film transistors (OTFT). More specifically, it would have been obvious that excessively large channel length would result in deteriorating on/off ratio, switching time, and cutoff frequency. An OTFT having a longer channel length would have a larger channel resistance, and thus, the on-current of the OTFT would be lowered. It is well known that an OTFT having low on-current is unfavorable especially in the field of organic electroluminescence devices because on/off ratio, one of the fundamental characteristics, of the OTFT is expected to be insufficient.

In the following calculations, the organic thin film transistor having a channel length of 100 μm prepared by *Klauk* (hereinafter referred as OTFT A) is compared to the organic thin film transistor having a channel length of 5 μm (hereinafter referred as OTFT B) in terms of source-drain current (on-current).

The following formula (A) is disclosed on page 77 in the English translation of the present specification:

$$I_D = (W/2L) \cdot C \mu (V_G - V_T)^2 \quad (A)$$

(In the formula, I_D represents an electric current between the source electrode and the drain electrode, W represents a channel width, L represents a channel length, C represents an electric capacitance per unit area of the gate insulator layer, V_T represents a gate threshold voltage, and V_G represents a gate voltage.)

Now, channel length (L), channel width (W) and gate voltage (V_G) of OTFT A and OTFT B are literally disclosed in the reference document. Carrier field•effect mobility (μ) and threshold voltage (V_T) are estimated from Fig.3 and Fig.4. Electric capacitance per unit area of a channel length (C) remains unknown but OTFT A and OTFT B should have the same value. The table below shows the estimated values and the result of the calculation.

	OTFT A	OTFT B
Channel length (L)	100μm	5μm
Channel width (W)	100μm	100μm
Gate voltage (V_G)	-5V	-5V
Carrier field-effect mobility (μ)	0.6 $cm^2/V \cdot s$	0.1 $cm^2/V \cdot s$
Threshold voltage (V_T)	0.5V	1.4V
Electric current between the source electrode and the drain electrode (I_D)	9.075 × C A	40.96 × C A

As shown above, I_D of OTFT A is lower than 1/4 I_D of OTFT B.

Moreover, it would have been also obvious that OTFT A would have lower cutoff frequency (f_T) and longer switching time (τ_r) because cutoff frequency (f_T) is inversely proportional to the square of channel length, and switching time (τ_r) is directly proportional

to the square of channel length. Cutoff frequency (f_T) and switching time (τ_r) of OTFT A and OTFT B are calculated according to the following formulae.

$$f f_T = \mu V_D / (2\pi L^2)$$

$$\tau_r = L^2 / (\mu V_D)$$

	OTFT A	OTFT B
Channel length (L)	100μm	5μm
Gate voltage (V_G)	-5V	-5V
Dainage (V_D)	-10V	-10V
Carrier field-effect mobility (μ)	0.6 $cm^2/V\cdot s$	0.1 $cm^2/V\cdot s$
Cutoff frequency	9.6×10^3 Hz	6.4×10^5 Hz
Switching time	1.67×10^{-5} s	2.5×10^{-7} s

As shown above, OTFT A has lower cutoff frequency and longer switching time.

Therefore, a person skilled in the art would not be motivated to lengthen the channel lengths of TFTs based on the disclosure of *Klauk*.

(ii) The organic light emitter of *Jackson* has a vertical structure, and has a light emitting layer, whereas the TFT of *Klauk* has a horizontal structure, and does not have a light emitting layer.

The light emitting device of *Jackson*, for example, disclosed in Fig.3 has three layers between the source and the cathode (drain electrode). Jackson mentions the thickness of the three layers on column 4 lines 54-56, saying "Film thickness is typically about 500 Å for pentacene layer 20, about 300 Å for TPD layer 32, and about 350 Å for Alq layer 22," the total thickness of these three layers being 115 nm. Further considering the dimensions of Fig.l, 3-5 and 8 disclosed by *Jackson*, it is obvious that none of these devices satisfies the distance between the source electrode and the drain electrode of the claimed invention.

Moreover, it is also obvious that a person skilled in the art is directed away from setting the distance between the source electrode and the drain electrode of *Jackson's* device to 1 μm or larger because the device has a horizontal structure containing a light emitting

layer. It is well known that Alq layer of a light emitting device is expected to be extremely thin, and otherwise, the favorable light emission property would not be exhibited, and perhaps the device may result in loosing light-emitting property.

With respect to the alleged obvious nature of incorporating the compounds of *Ueda* and *Taguchi* in the OTFT of *Jackson*, *Jackson* only states "it will be apparent to those skilled in the art that other small-molecule organic compounds or polymers may be used." The statement neither teaches any criteria in selecting a material for each layer, nor indicates any specific compounds. Aperson skilled in the art would not be motivated to use *Ueda's* or *Taguchi's* compounds based on such a broad, general and undistinguished disclosure.

Furthermore, please notice that modifying the organic light emitter of *Jackson* by replacing Alq with *Ueda's* or *Taguchi's* compound does not lead to the OTFT of amended claim 1 because the pentacene layer remains as the organic semiconductor layer. The organic light emitter of *Jackson* comprises an organic semiconductor layer (pentacene layer) and an organic light emitting layer (Alq layer) (see Summary of the Invention), and the functions of these two layers are clearly different. Also, *Jackson* nowhere indicates that the organic semiconductor layer includes a light emitting material.

Please also notice that the OTFT of the claimed invention exhibits unexpectedly high on/off ratios. The lowest on/off ratio confirmed among Examples 1-92 is 3.5×10^6 of Example 35, and an even higher on/off ratio is confirmed in the other Examples. In contrast, *Jackson* is silent with respect to on/off ratio, and the OTFTs of *Klauk* exhibit on/off ratios between 10^5 and 10^6. Accordingly, the claimed invention clearly exhibits unexpected effects.

Thus, as described above, since (a) the device structures of *Jackson* and *Klauk* are significantly different, (b) *Klauk* does not actually suggest lengthening channel length, (c) *Jackson* does not suggest the use of heterocyclic compounds of formulas (I)-(VII), and (d) Applicants' claimed OTFT exhibits unexpectedly high on/off ratios, the cited art of record

does not render obvious Applicants' claims. Accordingly, Applicants request withdrawal of the obviousness rejections in view of *Jackson* and *Klauk* in combination with either *Ueda* or *Taguchi*.

Conclusion

For the reasons discussed above, Applicants submit that all now-pending claims are in condition for allowance. Applicants respectfully request the withdrawal of the rejections and passage of this case to issue.

Respectfully submitted,

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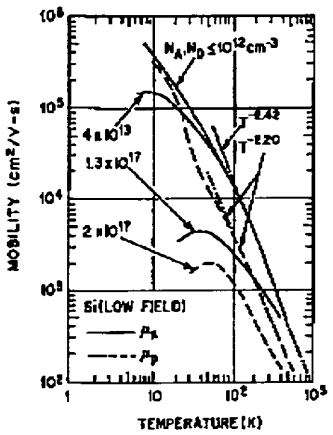

Fig. 19 Mobility of electrons and holes in Si as a function of temperature. (After Jacoboni et al., Ref. 37.)

For nondegenerate semiconductors, that is, where n is much smaller than N_C, Eq. 43a reduces to

$$D_n = \left(\frac{kT}{q}\right)\mu_n \tag{44a}$$

and similarly

$$D_p = \left(\frac{kT}{q}\right)\mu_p. \tag{44b}$$

Equations 44a and 44b are known as the Einstein relationship. At 300 K $kT/q = 0.0259$ V, and values of D are readily obtainable from the mobility results shown in Fig. 18. The mobilities discussed above are the conductivity mobilities, which have been shown to be equal to the drift mobilities.[37] They are, however, different from the Hall mobilities considered in the next section.

1.5.2 Resistivity and Hall Effect

The resistivity ρ is defined as the proportionality constant between the electric field and the current density J:

$$\mathcal{E} = \rho J. \tag{45}$$

Its reciprocal value is the conductivity, that is, $\sigma = 1/\rho$, and

$$J = \sigma\mathcal{E}. \tag{46}$$

For semiconductors with both electrons and holes as carriers, we obtain

$$\rho = \frac{1}{\sigma} = \frac{1}{q(\mu_n n + \mu_p p)}. \tag{47}$$

If $n \gg p$, as in n-type semiconductors,

$$\rho \simeq \frac{1}{q\mu_n n} \tag{48}$$

or

$$\sigma \simeq q\mu_n n. \tag{48a}$$

The most common method for measuring resistivity is the four-point probe method (insert, Fig. 20).[38,39] A small current from a constant-current source is passed through the outer two probes and the voltage is measured between the inner two probes. For a thin wafer with thickness W much smaller than either a or d, the sheet resistance R_s is given by

$$R_s = \frac{V}{I} \cdot \mathrm{CF} \qquad \Omega/\text{square} \tag{49}$$

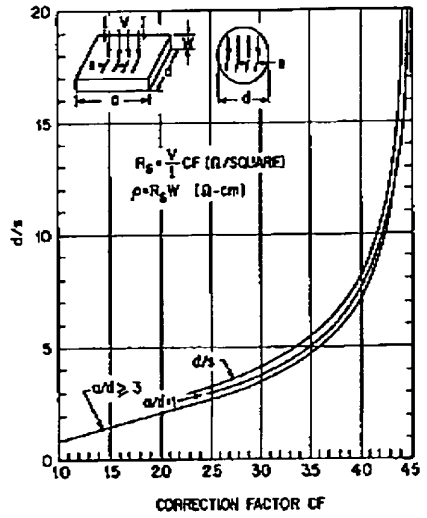

Fig. 20 Correction factor for measurement of resistivity using a four-point probe. (After Beadle, Plummer, and Tsai, Ref. 38.)